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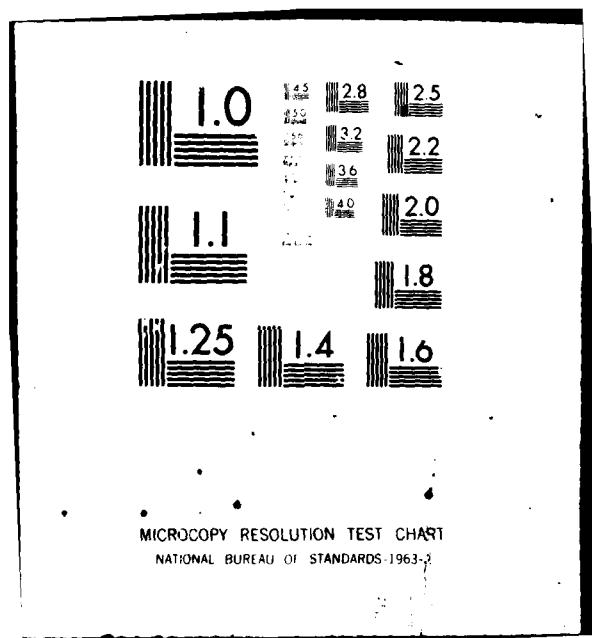
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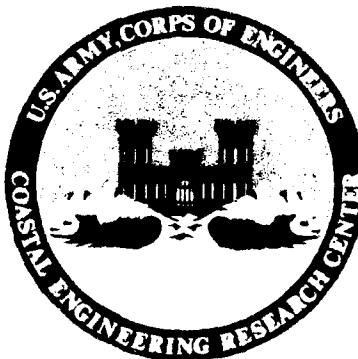
Volume II
Evaluation of Benthic Communities Adjacent to a
Restored Beach, Hallandale (Broward County), Florida

by

G. Alex Marsh, Philip R. Bowen, Donald R. Deis,
David B. Turbeville, and Walter R. Courtenay, Jr.

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MARCH 1980

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impact analysis of a fill project underway at Hallandale in September 1979.

Core samples at sand stations yielded 114 invertebrate species, not including nemerteans and oligochaete annelids. More than 90 percent of the fauna occurred at the two outer stations in densities of up to 17,144 individuals per square meter. Quadrat samples of reef biota showed a maximum abundance and diversity of corals, alcyonarians, and sponges in the middle and outer regions of the second reef. The reefs appeared in good condition, and showed no apparent effects from a 1971 beach nourishment project.

PREFACE

This report (Vol. II) is published to provide coastal engineers with an evaluation of benthic communities adjacent to a restored beach. Volume I provides a comprehensive study of the impact of beach nourishment and offshore borrowing on nearshore and coral reef fish populations. Both studies were conducted at Hallandale (Broward County), Florida. The work was carried out under the coastal ecology research program of the U.S. Army Coastal Engineering Research Center (CERC).

The report was prepared by Dr. G.A. Marsh, Associate Professor of Ecology; P.R. Bowen and D.B. Turbeville, candidates for the M.S. degree; D.R. Deis who recently completed his M.S. degree (now a biologist for the Florida Department of Environmental Regulation); and Dr. W.R. Courtenay, Jr., Professor of Zoology, Florida Atlantic University, Boca Raton, Florida under CERC Contract No. DACW72-77-M-0639.

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Comments on this publication are invited.

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TED E. BISHOP
Colonel, Corps of Engineers
Commander and Director

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CONVERSION FACTORS, U.S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U.S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	by	To obtain
inches	25.4	millimeters
	2.54	centimeters
square inches	6.452	square centimeters
cubic inches	16.39	cubic centimeters
feet	30.48	centimeters
	0.3048	meters
square feet	0.0929	square meters
cubic feet	0.0283	cubic meters
yards	0.9144	meters
square yards	0.836	square meters
cubic yards	0.7646	cubic meters
miles	1.6093	kilometers
square miles	259.0	hectares
knots	1.852	kilometers per hour
acres	0.4047	hectares
foot-pounds	1.3558	newton meters
millibars	1.0197×10^{-3}	kilograms per square centimeter
ounces	28.35	grams
pounds	453.6	grams
	0.4536	kilograms
ton, long	1.0160	metric tons
ton, short	0.9072	metric tons
degrees (angle)	0.01745	radians
Fahrenheit degrees	5/9	Celsius degrees or Kelvins ¹

¹To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use formula: $C = (5/9) (F - 32)$.

To obtain Kelvin (K) readings, use formula: $K = (5/9) (F - 32) + 273.15$.

EVALUATION OF BENTHIC COMMUNITIES ADJACENT TO A
RESTORED BEACH, HALLANDALE (BROWARD COUNTY), FLORIDA

by

*G. Alex Marsh, Philip R. Bowen, Donald R. Deis,
David B. Turbeville, and Walter R. Courtenay, Jr.*

I. INTRODUCTION

Some beach-front development practices have resulted in severe shoreline erosion along the Florida coastline. The problem is especially serious in southeastern Florida where over half of the 103.7 miles of recreational beaches in Palm Beach, Broward, and Dade counties have been listed by the Florida Department of Natural Resources as being in a "critical state of erosion."

The problem has required periodic nourishment projects, generally involving the dredging of sand from offshore deposits. The ecological effects of one such project was investigated by sampling sandy-bottom and reef-dwelling communities adjacent to a previously restored beach at Hallandale (Broward County), Florida. Results were compared with samples from similar communities in nearby Golden Beach (Dade County).

Sherk and Cronin (1970) provide a bibliography on the environmental effects of dredging and filling, although most of the reports focused on bays and estuaries. In Florida, the effects of shell dredging, channelization, and landfilling in the Boca Ciega and Tampa Bay areas have been well documented (Simon, Doyle and Conner, 1976; Simon and Doyle, 1974a, 1974b; Taylor, Hall, and Saloman, 1970; Taylor and Saloman, 1968; Sykes and Hall, 1970).

There is less information on the effects of offshore dredging for beach nourishment. Holland, Chambers, and Blackman's (1973) study of fish populations before and after a restoration project at Lido Key (Pinellas County), Florida, showed a temporary increase in fishes along the beach and near the borrow area. Saloman's (1974) study of an offshore borrow area created 3 years previously near Treasure Island (Pinellas County), Florida, revealed a decrease in the diversity and abundance of benthic invertebrates within the pit relative to adjacent areas. Marsh, et al. (1978) demonstrated greater abundance of benthic fauna in a borrow area off northern Broward County than on nearby undisturbed bottoms.

At Hallandale Beach, in southern Broward County, 268,000 cubic yards of dredged material was pumped ashore between 21 July and 21 September 1971. Courtenay, et al. (1974) subsequently surveyed the fishes and nearshore reef communities in this area

and reported considerable damage to the reefs immediately adjacent to the borrow site, although reefs closer inshore appeared to be relatively unaffected. Damage to the offshore reefs apparently resulted primarily from scouring and abrasion by dredging equipment.

The present study was designed as a quantitative post-nourishment assessment of benthic fauna in the same area surveyed by Courtenay, et al. (1974) at Hallandale Beach (Fig. 1).

Another beach restoration project began at Hallandale Beach in September 1979. The results of the present study will provide pre-nourishment data for use in assessing the impact of this second project.

II. DESCRIPTION OF AREA

The shelf topography off southeastern Florida is characterized by a linear series of steplike sandflats separated by elevated limestone outcrops which generally parallel the shoreline. These outcrops, or "reefs," are of Pleistocene origin (Duane and Meisburger, 1969) and support a great variety of sponges, alcyonarians, and stony corals. The sediments within the flats are white to gray calcareous sands and gravel consisting primarily of algal plates, shell fragments, foraminiferans, bits of coral skeleton, and other calcareous debris. The acid-soluble component of this sand is generally more than 80 percent.

In the immediate study area, off southern Broward County (Fig. 1), the narrow shoreface slope levels out at depths of 3 to 4 meters to form the inner flat. The shoreface slope is quite variable in extent and configuration, being highly influenced by the effects of waves, currents, and littoral sand supply.

Approximately 50 to 60 meters from shore, the inner sandflat is delimited by the first reef (Figs. 1 and 2), a low profile outcrop averaging about 50 meters in width. Much of the reef is often covered with a thin layer of sand, leaving only scattered patches of exposed limestone. The most conspicuous feature of the first reef is the scattered tufts of attached algae. Animal life is relatively scarce, represented primarily by a few sparsely distributed octocorals and reddish patches of boring sponge (*Cliona lampa*).

Seaward of the first reef is a sandy plateau averaging about 50 meters in width. This plateau terminates at the inshore edge of the second reef, a broad, rocky platform about 450 to 500 meters in width and occurring at depths of 7 to 8 meters. The second reef was more conspicuous than the first reef, with greater relief, more crevices and outcrops, and a large number of sea fans, sea whips, stony corals, sponges, and other marine invertebrates, as well as a great diversity of fishes. At the jagged outer edge of the second reef was a pronounced ledge, averaging about 1 meter in height, but reaching heights of 2 or more meters in some localities. Underwater visibility was usually excellent, and animal life was abundant along the outer ledge of the reef (Courtenay, Hartig, and Loisel, 1980).

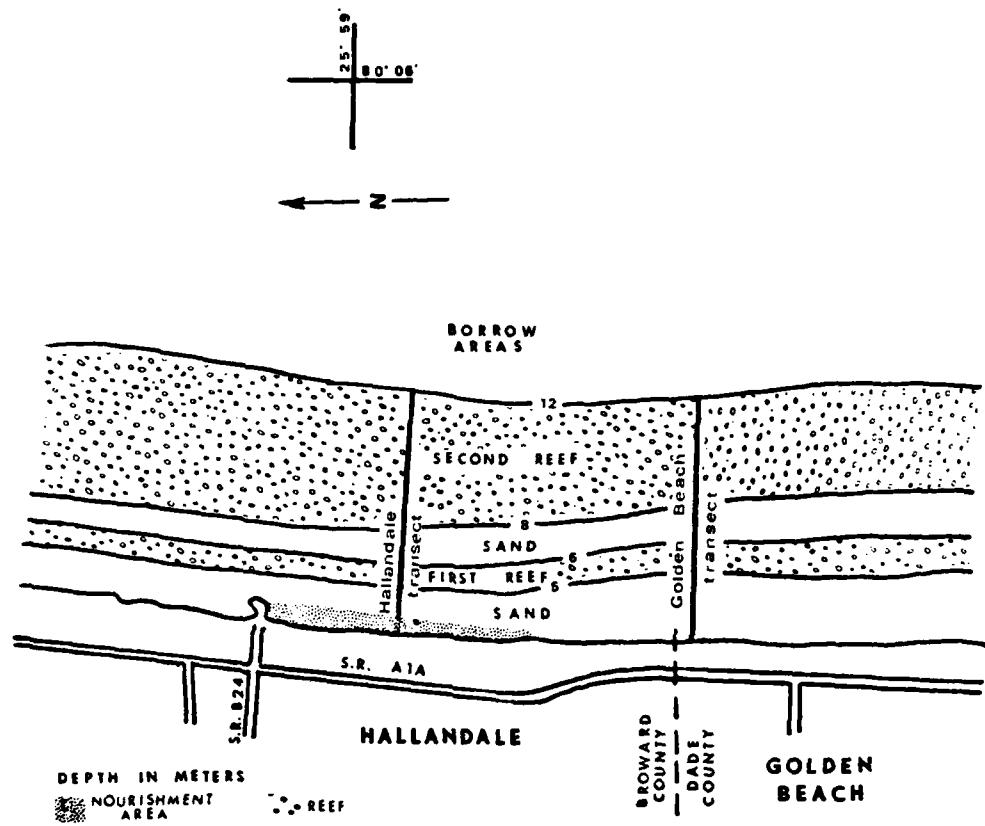


Figure 1. Location of transects off Hallandale (Broward County) and Golden Beach (Dade County).

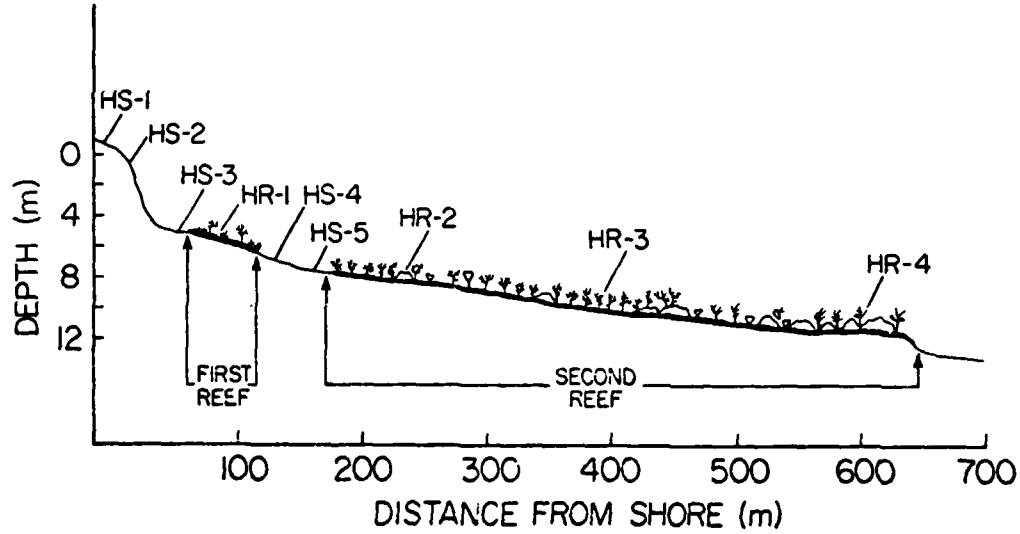


Figure 2. Schematic profile of Hallandale transect showing configuration of reefs and location of sandy-bottom (HS) and reef (HR) sampling stations.

Seaward of the second reef is another sandy plateau which, along most of the coastline of southeastern Florida, is bounded by yet a third well-developed rocky outcrop approximately 1.5 kilometers from shore at depths of 18 to 22 meters. Off southernmost Broward County, however, this third reef has only a few scattered limestone outcrops, and the sandy floor drops gradually to form the basin of the Florida Strait.

III. METHODS AND MATERIALS

Sampling stations at Hallandale Beach ($25^{\circ}58'56''$ N.) were established along a transect, perpendicular to the shoreline, extending from the intertidal zone through the second reef (Figs. 1 and 2), a distance of 650 to 700 meters. This transect included five sandy-bottom stations and four reef stations. Station HS-1 was located midway in the sandy intertidal zone 425 meters south of the rock jetty at the end of Hallandale Beach Boulevard (State Road 824). Two subtidal sandy-bottom stations were located between the shoreline and the first reef. Station HS-2 was on the shoreface at a depth of approximately 0.8 meter below mean sea level (MSL); HS-3 was about 1.0 meter from the inner edge of the first reef at a depth of approximately 5.0 meters below MSL. Stations HS-4 and HS-5 were located between the first and second reefs at depths of about 7.0 and 8.0 meters below MSL, respectively.

Reef stations on the Hallandale transect included one station (HR-1) near the center of the first reef and three stations (HR-2, HR-3, and HR-4) across the second reef.

For comparative purposes, a second transect, with stations in similar depths, was sampled at Golden Beach ($25^{\circ}58'27''$ N.) in northernmost Dade County, about 0.9 kilometers south of the Hallandale transect and away from the direct influences of the nourishment project. The shelf topography was generally similar to that at Hallandale, although the second reef was slightly farther offshore.

Sandy-bottom stations were sampled by scuba divers between 3 November and 15 December 1977. A hand-held PVC coring apparatus (Fig. 3) with a 7.9-centimeter inside diameter was used to collect 24 core samples at each station containing the top 11 centimeters of sediment, giving a total sampling area at each station of 0.118 square meters. Similar stations on the two transects were sampled on the same day, except at the outermost sand stations (HS-5 and GS-5) where mechanical problems and severe weather forced a 2-week interval between samplings. Samples were emptied individually into 1-gallon "Ziploc" storage bags, sealed, transported to the laboratory, and then washed through a 1.0 millimeter mesh screen and preserved in a 20 percent seawater-formalin solution stained with Rose Bengal. Animals were later sorted from the sediments and transferred to 70 percent ethanol.

An additional core sample was collected from each sandy-bottom station for sediment analysis. Particle-size distribution was determined by fractionation. Sediments were first dispersed



Figure 3. Core sampling at sandy-bottom stations.

for 24 hours in a 4 percent solution of sodium hexametaphosphate (Calgon), then washed through a 0.062-millimeter screen to separate the silts and clays from the sand. The sand was oven-dried at 90° Celsius for 12 hours, then shaken for 10 minutes in a graded series of nested sieves (U.S. Standard Sieve Series) corresponding to the Wentworth scale.

Organic content was determined by oven-drying an additional sediment aliquot, then measuring percent weight loss after incineration at 500° Celsius for 1 hour.

Carbonate content was determined by first washing a sediment sample with freshwater, drying it at 105° Celsius to constant weight, then adding dilute (10 percent hydrochloric acid until all carbonates had dissolved, as indicated by the lack of carbon dioxide bubbles. Samples were then washed again, dried, and weighed to the nearest 0.001 gram. Carbonate content was computed as percent weight loss.

Reef stations were sampled in late March 1978 (Fig. 4). At each station, three 1.0-square-meter areas of reef surface were photographed with a Nikonos III underwater camera fitted with a Honeywell 710 Strobonar flash. The areas photographed were randomly selected by dropping a 1.0-square-meter PVC frame onto the reef from an anchored boat. Kodachrome slides were later projected and analyzed by counting the number of epibenthic organisms belonging to the more common species, using reference specimens collected from the field to verify visual identifications. These quadrat analyses were supplemented by frequent observation dives along both transects throughout the duration of this study.

IV. RESULTS

1. Sediments.

Results of sediment analyses from all sand stations along both transects are shown in Table 1.

Particle-size distributions at the intertidal stations (HS-1 and GS-1) were characterized by a high proportion (> 90 percent) of sand grains larger than 0.25 millimeter in diameter. The mean grain size at Hallandale Beach (2.30 millimeters), however, was over twice that at Golden Beach (1.02 millimeters).

Conspicuous differences between transects were also evident at the shallowest subtidal stations (HS-2 and GS-2). At Hallandale Beach, particle-size distributions at HS-2 were generally similar to those at HS-1, although the mean grain size at HS-2 was greater (3.59 millimeters). At Golden Beach, a much larger proportion (74.7 percent) of particles was within the medium to fine sand category (0.5 to 0.125 millimeter), with the mean grain size only 0.196 millimeter.

At stations HS-3 and GS-3, located just within the first reef line, sediments were dominated (79.9 percent and 88.3 percent, respectively) by particles in the fine to very fine sand category,

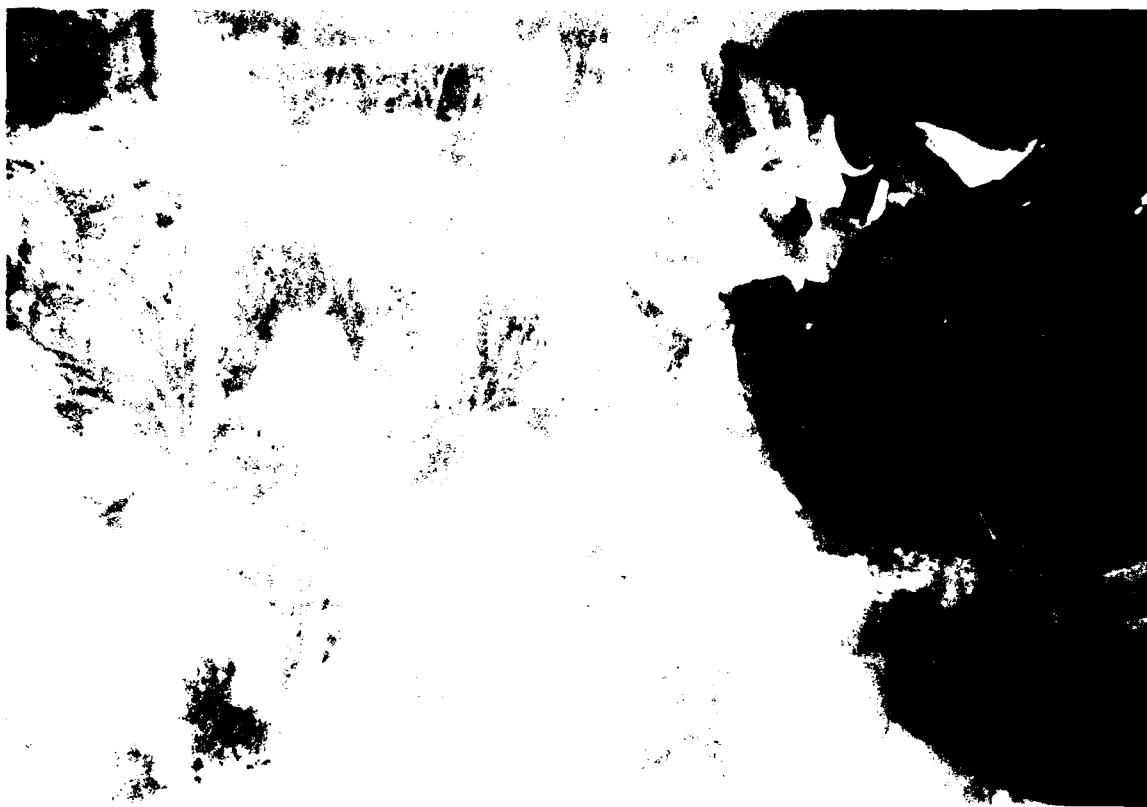


Figure 4. Quadrat sampling at reef stations.

Table 1. Sediment parameters at sandy-bottom stations off Hallandale Beach (HS) and Golden Beach (GS).

Station	Percent composition by grain size (mm)							Pct. carbonate	Pct. organic content	Mean grain size
	<2.0	1.0-2.0	0.5-1.0	0.25-0.5	0.125-0.25	0.063-0.125	<0.063			
HS-1	32.90	21.56	24.70	16.61	4.07	0.08	0.09	93.28	1.4	2.300
HS-2	32.98	24.24	23.72	16.41	2.23	1.01	0.28	85.90	1.4	3.590
HS-3	0.43	3.25	9.55	6.91	39.71	27.39	12.76	95.19	2.1	0.157
HS-4	4.40	34.25	44.86	14.15	1.54	0.38	0.44	95.16	1.9	0.829
HS-5	4.76	30.42	46.82	16.01	1.42	0.29	0.28	97.89	1.9	0.810
GS-1	39.00	14.48	16.28	21.05	8.79	0.14	0.25	90.00	1.5	1.020
GS-2	0.35	1.02	3.51	36.94	56.75	1.07	0.36	53.69	0.6	0.196
GS-3	0.42	1.17	3.26	6.87	54.62	30.95	2.72	91.97	2.1	0.155
GS-4	4.50	27.71	45.95	17.98	2.93	0.52	0.42	92.11	2.0	0.752
GS-5	28.65	34.10	26.95	7.57	1.59	0.68	0.45	97.85	2.3	6.480

with diameters less than 0.25 millimeter. These were the only stations which included a significant proportion of silts and clays (< 0.062 millimeter). The mean grain sizes at these two stations were essentially identical.

The first sand stations beyond the first reef (HS-4 and GS-4) were again characterized by a predominance of coarse and very coarse sands with similar mean grain sizes (0.829 and 0.752 millimeter).

At the outermost sand stations, located just inside the second reef, coarse and very coarse sands predominated on both transects. However, at Golden Beach, there was also a high proportion (28.65 percent) of particles larger than 2 millimeters. This fraction included many large calcareous fragments which appeared to be of echinoderm origin.

The carbonate fractions of sediments at all stations except HS-2 and GS-2 were in excess of 90 percent, which reflects the biogenic origin of most of these particles.

The organic content at all sand stations was very low, ranging from 0.6 to 2.3 percent and averaging only 1.7 percent on each transect.

2. Sandy-Bottom Fauna.

Core samples from the two transects yielded 114 species of benthic invertebrates, not including the oligochaete and nemertean worms which were not separated into lower taxa (Table 2). Most samples were dominated by polychaete annelids which comprised about one-half (49.1 percent) of the species recorded and 52.5 percent of the individuals. Oligochaete annelids, while not identified to species, were also important components of the community, comprising another 38.3 percent of the fauna. Crustaceans, mollusks, and all other invertebrate groups included more than one-half the species recorded, but only 9.2 percent of the total fauna.

The mean number of individuals (Fig. 5) and species (Fig. 6) per core at each sand station, within 95-percent confidence limits, were calculated (t-test) with reference to statistical tables in Rohlf and Sokal (1969). Differences and similarities within and between transects are readily apparent and are discussed below, along with a more detailed description of findings at each station.

a. Hallandale Beach. The most conspicuous feature in the distribution of this fauna was a pronounced increase in both density and diversity at the two outermost stations, which yielded 92 percent of the organisms collected (Figs. 5 and 6). Densities at stations HS-4 and HS-5, located between the first and second reefs, averaged approximately 30 times that of subtidal stations HS-2 and HS-3 inshore of the first reef.

Samples at intertidal station HS-1 yielded unexpectedly high densities of 1,530 individuals per square meter, based on extrapolated data. However, 66.1 percent of the fauna consisted of only one species, the cirolanid isopod, *Eurydice littoralis*. This isopod is sporadically abundant on beaches in tropical areas and may occur

Table 2. Species and numbers of individuals collected at sandy-bottom stations off Hallandale Beach (HS) and Golden Beach (GS).

	1	2	HS 3	4	5	1	2	GS 3	4	5
PHYLUM ANELIDA										
CLASS POLYCHAETA										
FAM SYLLIDAE										
<i>Exogone dispar</i>		1		174	193				247	262
<i>Syllis</i> sp. 1		2		164	68				157	164
<i>Syllis</i> sp. 2				3	33				17	14
<i>Eusyllis</i> sp.				3	4				1	10
<i>Brania clavata</i>					1					
<i>Eusyllinae</i> sp.				30	35				63	48
<i>Exogone</i> sp.					14					
<i>Autolytinae</i> sp.			1							
FAM MALDANIDAE										
<i>Axiothella mucosa</i>					22				2	1
<i>Maldanid</i> sp. 1		1			1					
FAM SPIONIDAE										
<i>Laonice cirrata</i>									2	
<i>Scolecolepides viridis</i>								75		
<i>Spionid</i> sp. 1								1		
<i>Prionospio cristata</i>		25	23	3				6	21	124
<i>Paraprionospio</i> sp.		78	123					31	21	26
FAM GONIADIDAE										
<i>Goniadid</i> sp. 1				32	27				28	5
FAM CIRRATULIDAE										
<i>Cirratulid</i> sp. 1				6	17				8	9
<i>Cirratulid</i> sp. 2				5	2				22	30
<i>Cirratulid</i> sp. 3									4	
FAM DORVILLEIDAE										
<i>Schistomerings rudolphi</i>				114	33				152	173
<i>Schistomerings caeca</i>				4	5					
FAM DINOPHILIDAE										
<i>Dinophilid</i> sp. 1				19	36					
FAM SIGALIONIDAE										
<i>Pholoe</i> sp.				2	7					
<i>Sthenelais</i> sp.					1					1
FAM CAPITELLIDAE										
<i>Dasybranchus</i> sp.	8		1							
<i>Capitellid</i> sp. 1						1			1	1
<i>Capitellid</i> sp. 2					2				1	
FAM PARAONIDAE										
<i>Aricidea</i> sp. 1		1		7	7					4
<i>Aricidea</i> sp. 2				97					91	170

Table 2. Species and numbers of individuals collected at sandy-bottom stations off Hallandale Beach (HS) and Golden Beach (GS).--Continued

	1	2	HS 3	4	5	1	2	GS 3	4	5
FAM ORBINIIDAE										
Orbiniid sp. 1			8	38	42			3	11	24
Orbiniid sp. 2		1								
FAM TEREBELLIDAE										
Terebellid sp. 1					1					
Terebellid sp. 2				5	20				89	
FAM OPHELIIDAE										
<i>Armandia agilis</i>						3	4	1	1	10
FAM LUMBRINERIDAE										
<i>Lumbrineris tenuis</i>					2			11		
<i>Lumbrineris acuta</i>				1				2		
FAM GLYCERIDAE										
Glycerid sp. 1	6	5	6					1	2	5
Glycerid sp. 2										
FAM NEREIDAE										
Nereid sp. 1			3	14				3		
Nereid sp. 2								5	6	
FAM MAGELONIDAE										
<i>Magelona</i> sp.	1	1								
FAM SABELLIDAE										
Sabellid sp. 1					5			6	1	
Sabellid sp. 2					5					
FAM ONUPHIDAE										
<i>Onuphis microcephala</i>			12	24				17	27	
FAM EUNICIDAE										
<i>Eunice vittata</i>									1	
<i>Eunice</i> sp. 1					4	4			2	
<i>Eunice</i> sp. 2										
FAM ARABELLIDAE										
Arabellid sp. 1								1		
FAM POECILOCHAETUS										
<i>Poecilochaetus</i> sp.							4			
FAM PHYLLODOCIDAE										
Phyllodocid sp. 1									1	
Phyllodocid sp. 2						1			1	
FAM AMPHINOMIDAE										
<i>Notopygus crinita</i>			2	1				1	9	
FAM LACYDONIIDAE										
Lacydonid sp. 1					2					

Table 2. Species and numbers of individuals collected at sandy-bottom stations off Hallandale Beach (HS) and Golden Beach (GS).--Continued

	1	2	HS 3	4	5		1	2	GS 3	4	5
FAM HESIONIDAE											
<i>Hesionid</i> sp. 1						1					
FAM PISIONIDAE											
<i>Pisionid</i> sp. 1						1					
FAM FLABELLIGERIDAE											
<i>Flabelligerid</i> sp. 1						2					
CLASS OLIGOCHAETA											
<i>Oligochaeta</i> spp.	2	25		423	1133		13	1	772	462	
PHYLUM PLATYHELMINTHES											
<i>Polyclad</i> sp. 1			1								
<i>Polyclad</i> sp. 2		3				1					
PHYLUM NEMERTEA											
<i>Nemertean</i> spp.	14			48	29		2	5	5	51	61
PHYLUM SIPUNCULA											
<i>Sipunculid</i> sp. 1						1				1	
PHYLUM MOLLUSCA											
CLASS BIVALVIA											
<i>Tellina aquistriata</i>						1					
<i>Tellina gouldii</i>						1					
<i>Tellina</i> sp. 1			2								1
<i>Tellina</i> sp. 2				1						3	3
<i>Pleuromeris tridentata</i>				6	41						
<i>Transennella stimpsoni</i>					4					1	
<i>Strigella mirabilis</i>			3							1	
<i>Limea</i> sp.				1	2						
<i>Bivalve</i> sp. 2					2				1		
<i>Bivalve</i> sp. 7					2				1	1	
<i>Bivalve</i> sp. 10									1		
<i>Bivalve</i> sp. 11								3			
<i>Bivalve</i> sp. 17					1						
CLASS GASTROPODA											
<i>Conus floridensis</i>						1					
<i>Calyptaea centralis</i>						1					
<i>Gabrielona sulcifera</i>						1				3	
<i>Zebina browniana</i>											1
<i>Cerodrillia perryae</i>											
<i>Turbanilla</i> sp.			2							2	
<i>Olivella</i> sp. 1											
<i>Olivella</i> sp. 2				1							
<i>Naticid</i> sp. 1					1						
<i>Gastropod</i> sp. 2					1					2	
<i>Gastropod</i> sp. 5										1	
<i>Gastropod</i> sp. 6										1	

Table 2. Species and numbers of individuals collected at sandy-bottom stations off Hallandale Beach (HS) and Golden Beach (GS).--Continued

	1	2	HS 3	4	5	1	2	GS 3	4	5
CLASS SCAPHIOPODA										
<i>Dentalim</i> sp.								1		
<i>Cadulus</i> sp.								1		
CLASS POLYPLACOPHORA										
<i>Polyplacophoran</i> sp. 1								1	1	
PHYLUM ARTHROPODA										
CLASS CRUSTACEA										
ORDER AMPHIPODA										
<i>Melita nitida</i>	2		1	10			6	2		10
<i>Platyischnopus</i> sp.		2						2		
<i>Trichophoxus floridanus</i>		1						13		
<i>Luconacia incerta</i>				18						
<i>Fallotritella biscayensis</i>				1						
<i>Sunchelidium americanum</i>								1		
<i>Bathyporeia parkeri</i>							11			
<i>Haustoriid</i> sp. 1							8	1		
<i>Gammarid</i> sp. 1				4			12	3		
<i>Gammarid</i> sp. 2							4	1		1
<i>Gammarid</i> sp. 3	6				1					4
<i>Gammarid</i> sp. 4									1	
<i>Gammarid</i> sp. 6									1	
ORDER ISOPODA										
<i>Ancinus depressus</i>	19									2
<i>Erichsonella floridana</i>										2
<i>Eurydice littoralis</i>	119									
<i>Sphaeromatid</i> sp. 2										2
<i>Horoloanthura irpex</i>							1			
ORDER CUMACEA										
<i>Cumacean</i> sp. 1				1			2	1		
<i>Cumacean</i> sp. 2								3		
<i>Cumacean</i> sp. 3							1			23
ORDER MYSIDACEA										
<i>Mysid</i> sp. 1				6					4	
ORDER TANAIDACEA										
<i>Tanaidacean</i> sp. 1										7
ORDER DECAPODA										
<i>Emerita talpoida</i>							1			
<i>Caridean larval</i> sp. 1					2					
<i>Caridean larval</i> sp. 2	23	5								
PHYLUM CHORDATA										
SUBPHYLUM CEPHALOCHORDATA										
<i>Branchiostoma caribaeum</i>				1					2	
TOTALS	180	50	56	1330	2017	11	134	57	1839	1712
NUMBER OF SPECIES	12	3	12	39	53	6	8	20	43	39

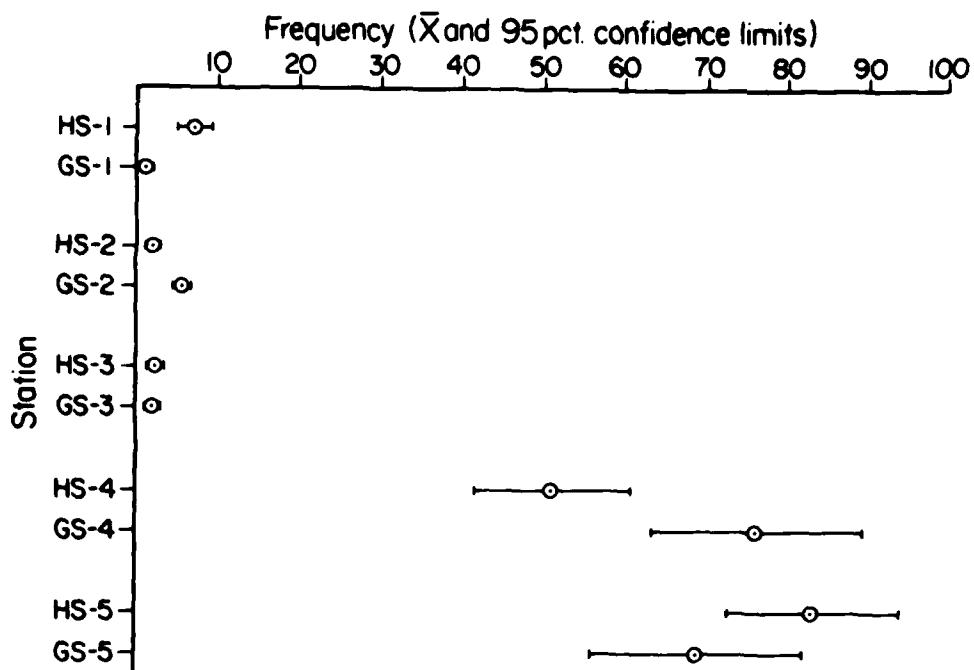


Figure 5. Mean number of individuals (95-percent confidence limits) at Hallandale and Golden Beach sand stations.

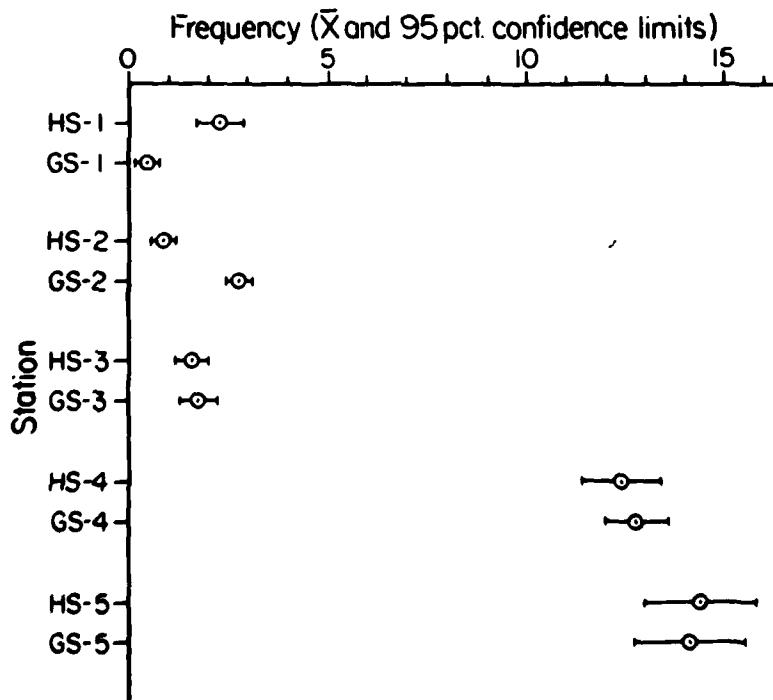


Figure 6. Mean number of species (95-percent confidence limits) at Hallandale and Golden Beach sand stations.

in the surf where it sometimes attacks swimmers (Schultz, 1969). Another isopod, *Ancinus depressus*, was also common at this station, followed by lesser numbers of small polychaetes, amphipods, and nemerteans.

Subtidal stations HS-2 and HS-3 were characterized by very low densities, ranging from 425 to 475 individuals per square meter, respectively. Exclusive of oligochaetes, stations HS-2 yielded the lowest number of species (three) collected from any station. The most abundant organism was an unidentified larval caridean. At station HS-3, just inside the first reef, the polychaete, *Prionospio cristata*, was the most common of 11 species collected, comprising 45.4 percent of the total sample.

In deeper water seaward of the first reef, stations HS-4 and HS-5 yielded extremely high densities of 11,305 and 17,144 individuals per square meter, respectively. Numbers of species also showed a sharp increase (Fig. 6) over the shallower stations; polychaete and oligochaete annelids were by far the dominant taxa. Oligochaetes were especially numerous at HS-5, where they comprised 52.7 percent of the total fauna.

b. Golden Beach. Station GS-1 yielded fewer species and individuals than any other station on this transect, as might be expected in the extreme environmental conditions within the intertidal habitat. Furthermore, the number of animals per square meter was considerably lower than at the equivalent station (HS-1) at Hallandale Beach (93.5 individuals per square meter compared to 1,530 individuals per square meter). Most of this difference between transects was due to the absence at Golden Beach of the two isopods (*Eurydice littoralis* and *Ancinus depressus*) which together made up over 75 percent of the fauna at Hallandale.

The shallowest subtidal station (GS-2) was significantly more productive than its counterpart at Hallandale, in terms of both numbers of individuals (Fig. 5) and species (Fig. 6). This station was dominated by the polychaete, *Scolecolepides viridis*; several species of amphipods were also common. Station GS-3 just inside the first reef, was about as productive in number of individuals and species as HS-3. As at Hallandale, the most abundant organism was the spionid, *Prionospio cristata*.

A great increase in species numbers and abundance was evident at stations GS-4 and GS-5 beyond the first and second reefs (Figs. 5 and 6) where densities reached 15,631 and 14,552 individuals per square meter, respectively. Similarities between transects at these offshore stations were manifested not only in their high productivity relative to the inshore stations but also in their faunal composition. At both Hallandale and Golden Beach, the most abundant organisms were the oligochaete worms and two species of syllid polychaetes, *Exogone dispar* and *Syllis (Typosyllis)* sp. 1, which occurred only at stations beyond the first reef. Except for station HS-4, no significant differences ($p < 0.05$) were found within or between transects for these outer stations, either in numbers of individuals (Fig. 5) or species (Fig. 6).

3. Reef Biota.

a. Hallandale Beach. The low profile first reef off Hallandale Beach was marked most conspicuously by scattered tufts of filamentous red algae, primarily *Gracilaria* sp. and, to a lesser extent, *Corynomorpha clavata* (Fig. 7). The coralline red alga, *Amphiroa fragilissima*, and the brown alga, *Dictyota* sp., were also common along with the green algae, *Udotea conglutinata*, *Halimeda opuntia*, and *Ulva lactuca*.

Marine invertebrates on the first reef were notably scarce, represented primarily by octocorallians (mostly *Pseudopterogorgia acerosa* and *Eunicea* spp.). Stony corals were very small and sparsely distributed, and sponges, mostly the heavenly sponge (*Dysidea etherea*), were noted only occasionally. The scarcity of marine animals on the first reef was probably due in part to the generally turbid conditions. Most species of reef fauna, particularly corals, are highly susceptible to siltation and are generally restricted to clear, sediment-free waters. Also, most of the limestone surface of the first reef was covered by a thin layer of sand which probably discouraged the settling and attachment of sessile fauna.

Underwater visibility was generally good on the second reef due to the greater depth and decreased wave surge. Algae along the inner edge of the reef were represented by the same species present on the first reef, with *Udotea conglutinata* the most abundant. The inshore edge of the second reef was populated by a greater number and variety of octocorallian and madreporean corals than the first reef, although these corals were still fairly sparsely distributed. Both groups became more abundant toward the interior and outer edge of the reef. Several species of *Eunicea* and *Pseudopterogorgia* were fairly common inshore, as well as the large star coral (*Montastrea cavernosa*), the clubbed-finger coral (*Porites porites*), and the star coral (*Favia fragum*). Sponges were represented primarily by the red sponge (*Haliclona rubens*) and the boring sponge (*Cliona lampa*). Several specimens of the long-spined urchin (*Diadema antillarum*) were also noted.

Toward the center of the second reef (Fig. 8) the density and diversity of fauna greatly increased, although the algae were somewhat less abundant than at shallower depths. In particular, *Udotea conglutinata*, which had been dominant near the inshore edge of the reef, was virtually absent; *Gracilaria* sp. was the only common algal species. Soft corals were especially abundant and represented by many species, including *Plexaura flexuosa*, *Muricea atlantica*, and several species of *Eunicea*. Stony corals were primarily rose coral (*Manicina areolata*), staghorn coral (*Acropora cervicornis*), and the large star coral (*Montastrea cavernosa*). Hydrocorals (*Millepora alcicornis*) and a variety of sponges were also common. Motile crustaceans, including arrow crabs (*Stenorhynchus seticornis*), banded coral shrimp (*Stenopus hispidus*), and spiny lobsters (*Panulirus argus*), were often observed among sponges and corals or in crevices within the pitted limestone surface.

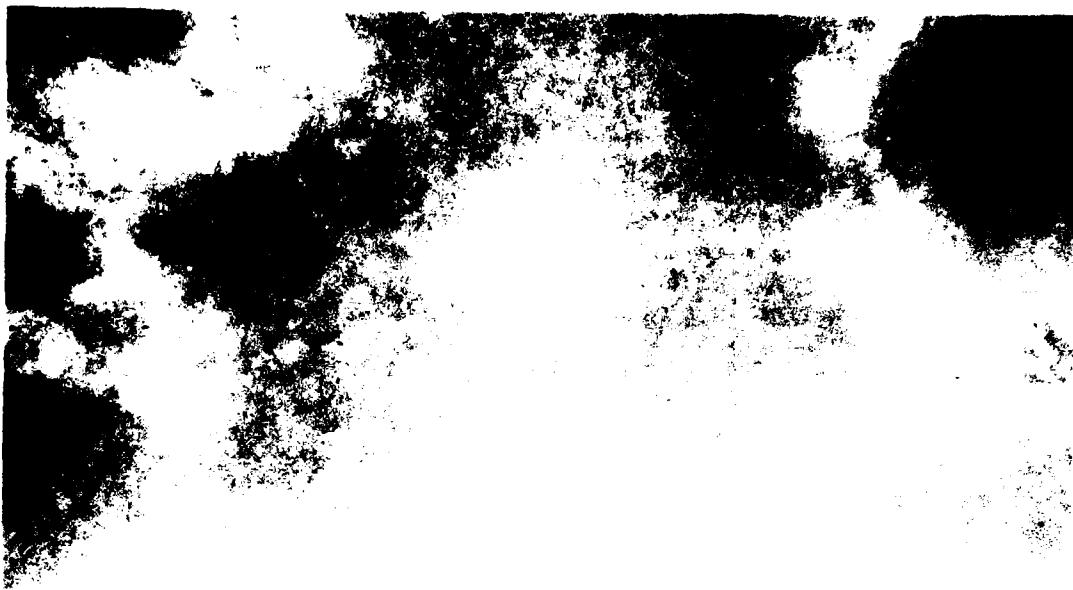


Figure 7. First reef off Hallandale showing clumps of attached algae.

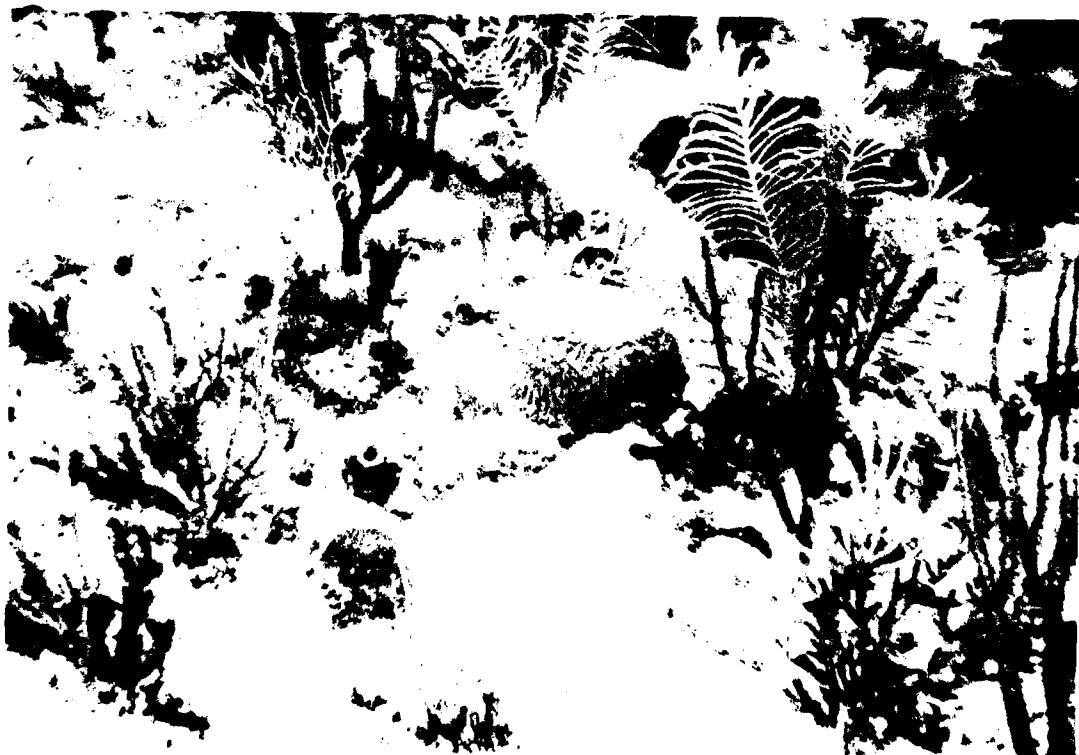


Figure 8. Second reef off Hallandale near station HR-3.

The abundance of fauna and the complexity of the reef surface were greatest near the offshore edge of the second reef. Stony corals were numerous at this location, with *Montastrea cavernosa* the dominant species. Other common species included the clubbed-finger coral, the common brain coral (*Diploria strigosa*), and the rose coral (*Manicina areolata*). Octocorallians were very conspicuous, especially *Eunicea* spp.; *Pseudopterogorgia acerosa* and the common sea fan (*Gorgonia ventalina*) were also among the more abundant species. Sponges were well represented, with *Haliclona rubens* by far the most common species; the vase sponge (*Ircinia campana*), the chicken liver sponge (*Chrondrilla nucula*), and numerous other species were also present. The long-spined sea urchin (*Diadema antillarum*) was more abundant at this locality than at any other reef station. Less conspicuous, but also common, was the pencil urchin (*Eucidaris tribuloides*). Spiny lobsters were often observed beneath the outer ledge. Algae were notably scarce at the outer edge of the second reef, with the exception of *Dictyota* sp.

Results from quadrat samples of the Hallandale Beach reef stations are shown in Table 3. For each station, the total number of specimens of each of the more abundant or conspicuous faunal species occurring in three 1.0 square meter quadrats is indicated. The relative abundance of algal species is also shown. Despite the obvious difficulties involved in quantifying colonial organisms, each species of which may vary greatly in size or area coverage, the quadrat samples substantiate the more subjective visual impressions of each part of the reefs. The scarcity of fauna on the first reef, the decrease in the abundance of algae at greater depths, and the increased density and diversity of sponges, alcyonarians, and hard corals toward the middle and outer parts of the second reef, are all apparent from these data. The density of soft corals, based on quadrat samples, was greater in the interior of the second reef (HR-3) than at the other stations. The average density at HR-3 was 10.7 colonies (all species) per square meter, compared to 3.7 colonies per square meter at HR-1 and 6.0 colonies per square meter at both HR-2 and HR-4.

b. Golden Beach. As at Hallandale Beach, the first reef off Golden Beach was populated mostly by clumps of attached algae, including primarily the rhodophytes, *Gracilaria* sp. and *Corynomorpha clavata*. *Dictyota* sp. and *Udotea conglutinata* were among several other fairly common algae.

Animal life on the first reef was poorly represented. A few widely scattered alcyonarians, including *Eunicea succinea* and *Pseudopterogorgia acerosa*, and an occasional small madreporean were the most conspicuous faunal elements. A few reddish-orange patches of the boring sponge (*Cliona lampa*) occurred on the limestone surface. The only motile fauna noted was an occasional urchin (*Lytechinus variegatus*).

Along the inshore edge of the second reef off Golden Beach, the outcrop had a more solid, discrete structure than at Hallandale where numerous patches of loose rubble formed a transitional zone.

Table 3. Abundance of organisms occurring in three 1.0-square-meter quadrat samples at each reef station off Hallandale Beach and Golden Beach.¹

	Hallandale Beach				Golden Beach			
	HR-1	HR-2	HR-3	HR-4	GR-1	GR-2	GR-3	GR-4
DIVISION CHLOROPHYTA								
<i>Halimeda opuntia</i>	C				0			
<i>Udotea conglutinata</i>	C	A	0		0	0		
<i>Ulva lactuca</i>	C	0			0			
DIVISION PHAEOPHYTA								
<i>Cladosiphon occidentalis</i>	O				0			
<i>Dictyota</i> sp.	C	0	0	C	C	0		0
DIVISION RHODOPHYTA								
<i>Amphiroa fragilissima</i>	C				C			
<i>Corynomorpha clavata</i>	C				A			
<i>Gracilaria</i> sp.	A	A	C		A	0		
PHYLUM PORIFERA								
<i>Callyspongia plicifera</i>			1					1
<i>Callyspongia vaginalis</i>				2				1
<i>Chondrilla nucula</i>				1				
<i>Ciona lampa</i>		8	1		1	3	15	
<i>Dysidea etheria</i>	1				2			
<i>Haliclona rubens</i>		1	1	10		1	7	2
<i>Haliclona variabilis</i>			1					
<i>Iotachota birotulata</i>			1	1				4
<i>Ircinia campana</i>			1	1				1
<i>Microciona prolifera</i>								1
<i>Speciospongia vesparia</i>				1				
<i>Xestospongia</i> sp.			2					1
PHYLUM CNIDARIA								
CLASS ANTHOZOA								
SUBCLASS OCOTOCORALLIA								
<i>Eunicea fusca</i>						1	2	
<i>Eunicea palmeri</i>			1			1		1
<i>Eunicea succinea</i>	1	2	7	3	1	6	8	4
<i>Eunicea</i> sp. 1		1		4			4	3
<i>Eunicea</i> sp. 2		4	4	2				1
<i>Eunicea</i> sp. 3						2		
<i>Eunicea</i> sp. 4						3		
<i>Eunicea</i> sp. 5	1		5			4	2	5
<i>Eunicea</i> sp. 6	2		4	3	3	10		2
<i>Gorgonia ventalina</i>				1				
<i>Muricea atlantica</i>			2					2
<i>Muricea muricata</i>								
<i>Plexaura flexuosa</i>			3			10		3
<i>Plexaurella grisea</i>								

Table 3. Abundance of organisms occurring in three 1.0-square-meter quadrat samples at each reef station off Hallandale Beach and Golden Beach.--Continued

	Hallandale Beach				Golden Beach			
	HR-1	HR-2	HR-3	HR-4	GR-1	GR-2	GR-3	GR-4
PHYLUM CNIDARIA								
CLASS ANTHOZOA								
SUBCLASS OCTOCORALLIA								
<i>Plexaurella</i> sp. 1				1				
<i>Plexaurella</i> sp. 2			6	1				
<i>Pseudopterogorgia acerosa</i>	10	5		1	1	2	2	1
<i>Pseudopterogorgia</i> sp. 1		3		2				
SUBCLASS ZOANTHARIA								
<i>Acropora cervicornis</i>				4				
<i>Dichocoenia stokesii</i>				1	1	1	2	1
<i>Diploria strigosa</i>				1	1			
<i>Eusmlia fastigiata</i>							1	
<i>Favia fragrum</i>	1	2	2					
<i>Manicina areolata</i>							1	
<i>Meandrina meandrites</i>						1	1	1
<i>Montastrea cavernosa</i>	1	3	8			1	4	3
<i>Porites porites</i>	1	3	8			1	4	3
<i>Siderastrea siderea</i>								
<i>Stephanocoenia michelini</i>								
CLASS HYDROZOA								
<i>Millepora alcicornis</i>				2	1			1
PHYLUM MOLLUSCA								
CLASS BIVALVIA								
<i>Lithophaga nigra</i>							9	
<i>Spondylus americanus</i>								1
PHYLUM ECHINODERMATA								
CLASS ECHINOIDEA								
<i>Diadema antillarum</i>								
<i>Eucidaris tribuloides</i>				1			2	
<i>Lutechinus variegatus</i>				1	1			
PHYLUM ARTHROPODA								
CLASS CRUSTACEA								
<i>Parulirus arcus</i>					1			
<i>Stenorhynchus seticornis</i>				1				
<i>Stenopus hispidus</i>				2	1			
PHYLUM CHORDATA								
SUBPHYLUM UROCHORDATA								
CLASS ASCIDIACEA								
<i>Clavelina picta</i>								1

¹ Algae are designated as A (abundant), C (common), and O (occasional).

Algae, chiefly *Dictyota* sp., *Udotea conglutinata*, and *Gracilaria* sp., occurred on this part of the reef but were not nearly as abundant as at Hallandale. The most conspicuous fauna were the soft corals, *Eunicea* spp. and *Pseudopterogorgia acerosa*. Several species of hard corals were also common, with *Montastrea cavernosa* the dominant species. Many of the hard corals in this area appeared diseased or damaged; the causes of these conditions could not be determined. Sponges, represented primarily by *Cliona lampa* and *Haliclona rubens*, were more common than on the first reef; although several long-spined urchins were usually visible, they increased in abundance toward the seaward edge of the reef.

The midpart of the second reef was dominated by a wide variety of octocorals (primarily *Eunicea* spp.), madreporearians, and sponges. The large star coral, *Montastrea cavernosa*, the star corals, *Stephanocoenia michelini* and *Dichocoenia stokesii*, and the flower coral, *Eusmilia fastigiata*, were a few of the more abundant species. The hydrocoral, *Millepora alcicornis*, and the red sponge, *Haliclona rubens*, were also common. Algae were scarce, more so than at equivalent localities off Hallandale Beach.

Conditions along the outer edge of the second reef (Fig. 9) were very similar to those at Hallandale Beach. The irregular and pitted substrate was invested with numerous soft corals, hard corals, and sponges. One of the most striking similarities was the occurrence of *Dictyota* sp. which, as at Hallandale, was the only conspicuous algal species present. *Diadema antillarum* and small motile fauna occurred within the holes and crevices in the reef and among the larger sponges and corals.

Results from quadrat samples at reef stations off Golden Beach are shown in Table 3. The distribution patterns of organisms are generally similar to those at Hallandale Beach. Although the maximum density of soft corals at Golden Beach (14.0 colonies per square meter at GR-3) was greater than at Hallandale (10.7 colonies per square meter at HR-3), the same within-transect pattern prevailed. The decreased abundance of alcyonarians at the outermost reef stations on both transects may have been due to the increased coverage of stony corals, leaving less available substrate for attachment.

V. DISCUSSION AND CONCLUSIONS

The composition and structure of shallow-water benthic communities are determined by many environmental factors. Sediment type, light intensity, temperature, turbulence, and various biological interactions are among the more important of these factors. In southeastern Florida, man-induced disturbances, such as those resulting from beach nourishment projects, represent an additional influence.

The most striking pattern in the distribution of sandy-bottom communities within the study area was the great increase in species diversity and density at the offshore stations. More than



Figure 9. Reef fauna near outer edge of second reef off Golden Beach.

90 percent of the fauna on both transects was collected from the two stations seaward of the first reef, and more than 60 percent of the species at each transect occurred exclusively at these stations.

Benthic stations sampled in this study represented a wide range of environmental conditions. The intertidal zone of open sandy beaches is one of the most rigorous and variable of all marine habitats, requiring unique adaptations among the fauna inhabiting this zone. These organisms must either be able to migrate with the tides or be able to withstand exposure to great extremes and rapid fluctuations in temperature, salinity, and numerous other variables which may occur within a given tidal cycle. Since relatively few marine animals have been able to adapt to these conditions, the diversity of intertidal macrofauna is characteristically low, as indicated in this study.

In shallow subtidal areas, although conditions for life become more favorable with regard to many factors, the turbulence of the water, suspended sediments, and the instability of the substrate create conditions which are not conducive to the establishment of stable, diverse benthic communities. At various times of the year, especially during periods of high winds and rough seas, large amounts of sand may shift on and off the shore in response to strong wave surge and tidal currents, causing unusually dynamic and hazardous conditions for most forms of benthic life. The low species diversity and sparse numbers of animals found in these localities reflect these conditions.

In deeper water seaward of the first reef, the benthic habitat becomes much less affected by wave surge and turbulence. The stability of the substrate and the relative uniformity of physical and chemical conditions promote the development of a diverse and productive benthic community such as found at the seaward stations.

Differences in the composition and structure of reef communities along each transect also reflect differences in the physical environment. Most species of sponges, alcyonarians, and stony corals, the most conspicuous reef fauna, are highly susceptible to siltation. The scarcity of these forms on the first reef probably resulted partly from the turbulence of the water and from the relatively large amounts of sediments in suspension. The low profile of the first reef, its lack of structural complexity, and the presence of a thin layer of sand over much of the limestone surface, contributed to the low diversity and abundance of animal life at this locality.

On the broad second reef, especially toward the outer edge, the greater depths and clear waters, as well as the increase in structural complexity of the reef surface, were much more favorable for the existence of a rich and diverse fauna. The many holes and crevices within the limestone base provided a greater surface area for the attachment of sessile forms as well as shelter for various motile crustaceans and echinoderms. Finally, the presence of the larger sponges and corals added to this complexity and increased the availability of niches for smaller organisms.

Differences between transects at the reef stations appeared minor and primarily concerned differences in relative abundance of only a few species. These differences could be attributed to any number of factors, not necessarily related to past dredging activities.

For sandy-bottom stations, except for the relatively low number of individuals at HS-4, the only significant differences in density or diversity between transects occurred at intertidal stations HS-1 and GS-1 and shallow subtidal stations HS-2 and GS-2. Since sediment particle size is an important determinant of the distribution and abundance of benthic organisms, the fact that sediments at HS-1 and HS-2 were considerably coarser than at GS-1 and GS-2 (Table 1) may account for these differences. The greater pore-space available in the intertidal zone at Hallandale may have provided a more favorable habitat for the isopods, *Eurydice littoralis* and *Ancinus depressus*, which were common at HS-1 but absent from GS-1. Subtidally, the greater abundance of fauna (primarily small polychaetes and amphipods) at GS-2 than at HS-2 may have been favored by the smaller grain sizes.

A direct comparison between the results of this study and those of Courtenay, et al. (1974) can not be made. The earlier study was essentially a qualitative survey of the fishes and more conspicuous reef fauna at Hallandale Beach and several other localities in Palm Beach and Broward Counties. Sandy-bottom communities were not investigated, and few quantitative measures were made of the reef fauna. Although the number of species observed by Courtenay, et al. (1974) is greater than recorded in this study (Table 3), the difference is apparently due to sampling technique. In the earlier study, samples were selectively collected over a large area of the reef rather than from randomly selected quadrats. Hence, more of the less common species were included in their findings. No evidence was found in the present study of the "substantial damage" to part of the reef adjacent to the borrow area during the 1971 dredging operation as reported by Courtenay, et al. (1974). This damage included scouring of reef edges by dredging equipment and suffocation of coral by siltation. Either this area was not located in this study, or the damage is no longer evident.

Observations in this study at Hallandale and Golden Beach indicate that no lasting effects of beach restoration are apparent. Although many coral heads and alcyonarians along both transects showed evidence of disease or damage, dredging could not be clearly implicated, and the reefs appeared in no way distinct from others along the Broward County coastline.

VI. RECOMMENDATIONS

Because of high productivity and diversity of shallow-water marine habitats off southeastern Florida, and because of the great potential for environmental damage resulting from coastal

engineering projects, precautions should be taken to preserve the ecological integrity of these areas. This is particularly important where dredging or filling is conducted near coral reefs. Sandy-bottom habitats are populated primarily by small, short-lived organisms with great reproductive potential; consequently, these communities recover rather quickly from environmental disturbances. Rocky outcrops and coral reefs, on the other hand, provide a substrate and shelter for a great many larger organisms and longer living colonial forms, such as sponges, alcyonarians, and stony corals, which are highly susceptible to siltation or scouring and are incapable of repopulating quickly following a disturbance.

To assess the environmental impact of beach nourishment, these projects should be preceded by quantitative surveys of the project area. Surveillance of nearby reefs should also be maintained during dredging, followed by postnourishment surveys of these same areas. Where possible, photographic documentation should be provided.

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